

# The Health Status of the Population Neighbouring the Nuclear Power Plants in Slovakia

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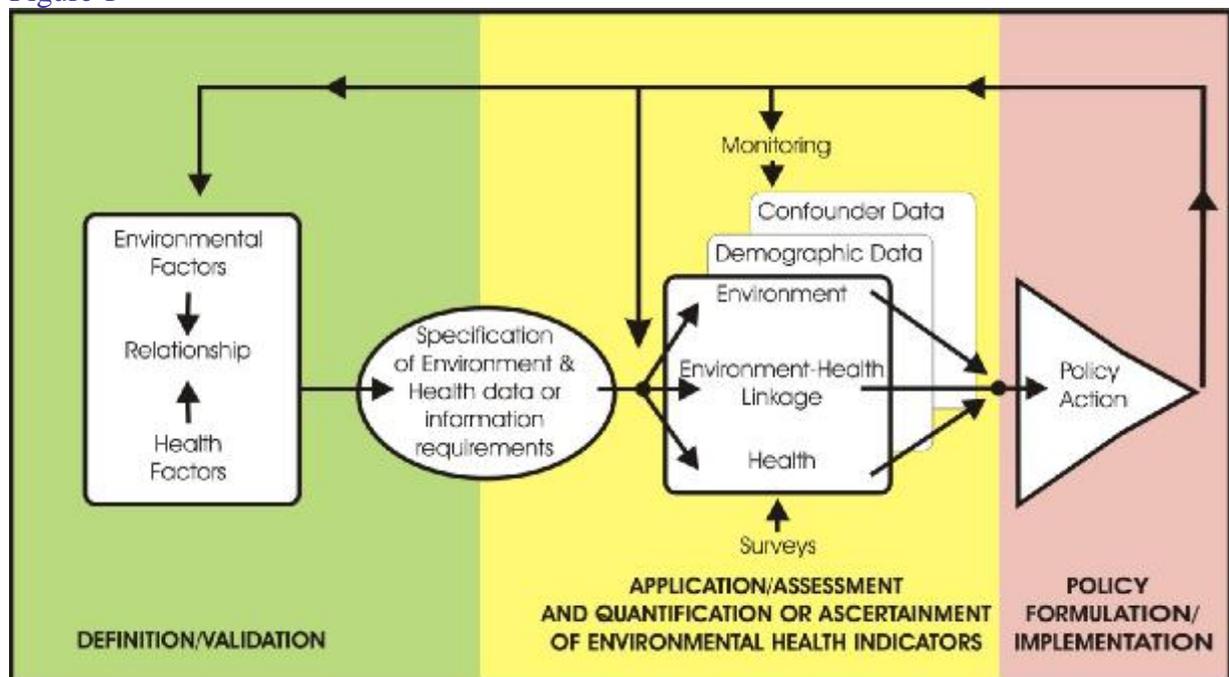
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## Introduction

Nuclear power plants are regarded as potential sources of low doses of ionising radiation. We therefore consider it important to assort and evaluate health and environmental analyses focused on their influence, so that we can react promptly in case of necessity.

The whole process of the monitoring and investigation of the health condition of the population, as well as the resulting decisions, is characterised best by the following scheme – carefully applied and checked continuously as to its proper functioning.

Figure 1



(D.Briggs, C.Corvalán, M.Nurminen: Linkage methods for environment and health analysis, WHO, Geneva, 1996)

## Study Aim

Our objective is to ascertain the actual state of the indicators of health in individual villages within the area under investigation, to ascertain the trend of the development of indicators in the area surrounding the nuclear power plant included in the study, to find whether the occurrence of an indicator is accidental or whether it is determined in the village, make a comparison with another area and with the situation in the Slovak Republic as a whole and, consequently, to determine possible influence of the Power Plant on the indicator's value.

### *We follow several lines*

- we ascertain which health indicators can be gathered on desired level of accuracy and reliability
- we select those that are relevant and calculate them in order to be able to make comparisons in all the villages of the Slovak Republic
- we determine the health risk of the power plant as a point source by special mathematic methods from selected and calculated indicators and determine if there is a correlation between the rate of an indicator and the operation of the nuclear power plant.

### Health Indicators

We use methods applied in the field of population epidemiology and focus our interest on the health condition of the selected population as a whole, described in its entirety by the complete range of health indicators. We do not follow the fate of any concrete individuals or any specific diseases.

Used are indicators calculated from basic demographic calculation operations and national registries of diseases.

Selection of indicators and their calculation is performed in accordance with the recommendations of the World Health Organization (WHO) in Geneva.

The complete set of indicators according to WHO being quite extensive, a selection was made of those followed in the official national statistics and therefore warranted by the state. A further narrowing of the selection was made taking into account possible impact of the power plant's operation on human health.

The health indicators were calculated for each village in Slovakia individually and they were evaluated separately for each village in the territory of a power plant.

The population in power plants' neighbourhood and, for the sake of comparison, also the entire population of Slovakia, are evaluated by means of health indicators.

### *Criteria for Environmental Health Indicators :*

- followed on the entire territory of Slovakia, to enable territorial comparisons followed long-term and continuously, if possible without any significant interruptions
- collected by the same, internationally accepted methodology
- verified by the state authority
- and, of course, still valid

A total of 43 individual health indicators were followed which characterise the demographic composition of the population in a village, reproductive health, morbidity due to selected diseases, total and premature mortality, as well as mortality caused by selected diseases.

For the purpose of mathematical analyses the following 15 indicators are used:

**Table 1 Selected indicators analysed by fuzzy c-cluster analysis**

Indicator	Contents	Selection reason
1	<i>PYLL100</i> Potential Years of Life Lost (PYLL) per 100.000 Inhabitants	Premature Mortality
2	<i>PYLL1</i> Potential Years of Life Lost (PYLL) per one Death	Premature Mortality
3	<i>REC00</i> Number of total Cancer Deaths per 100.000 Inhabitants (classified as C00 – C99 in the ICD, ver.10)	Selected Causes of Death
4	<i>REC1526</i> Number of Alimentary Canal Cancer Deaths per 100.000 Inhabitants (classified as C15 – C26 in the ICD, ver.10)	Selected Causes of Death
5	<i>REC9195</i> Number of Leukaemias Deaths per 100.000 Inhabitants (classified as C91 – C95 in the ICD, ver.10)	Selected Causes of Death
6	<i>REC34</i> Number of Lung Cancer Deaths per 100.000 Inhabitants (classified as C34 in the ICD, ver.10)	Selected Causes of Death
7	<i>REI00</i> Number of Cardiovascular System Deaths per 100.000 Inhabitants (classified as I00 – I99 in the ICD, ver.10)	Selected Causes of Death
8	<i>HUS</i> Total Mortality (Number of Deaths per 1000 Inhabitants)	Basic Indicator of the Mortality
9	<i>HUM</i> Total Male Mortality (Number of Male Deaths per 1000 Men)	Basic Indicator of the Mortality
10	<i>HUZ</i> Total Female mortality (Number of female Deaths per 1000 Women)	Basic Indicator of the Mortality
11	<i>PUS</i> Proportion of Premature Deaths (before the Age of 65 Years)	Basic Indicator of the Premature Mortality
12	<i>PUM</i> Proportion of Premature Male Deaths (before the Age of 65 Years)	Basic Indicator of the Premature Mortality
13	<i>PUZ</i> Proportion of Premature Female Deaths (before the Age of 65 Years)	Basic Indicator of the Premature Mortality
14	<i>PPOD</i> Proportion of liveborn Children with low Birth Weight under 2500 Grams	Reproduction Malformation
15	<i>SPOTPOT</i> Proportion of spontaneous Abortions per total Conception	Reproduction Malformation

We will analyse in detail some of them as a sample and then draw a conclusion from all.

### *Data*

Data necessary for the calculation of indicators are obtained from the following sources:

- The complete Register of Deaths, The Register of Births, and The Register of Abortions in Slovakia in 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000 ( State Statistics of the Slovak Republic)
- The complete balance of the villages, age structure of the villages in 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000 ( State Supernumerary of the Slovak Republic)
- National register of Chronic Lung Diseases and the national register of Tuberculosis ( The National Institute of Tuberculosis and Respiratory Diseases)
- The land register of the villages according to map letters in ARC VIEW dated 1996
- Structure of pollution from the nuclear power plant Bohunice and the nuclear power plant Mochovce for the years followed.

We examined the health of the population living in the vicinity of nuclear power plants in an area specified in the protection area guidelines, in the case of the nuclear power plant Bohunice within the radius of 30 km and in the case of the Nuclear Power Plant Mochovce within the 20 km radius.

Regular reports on the health condition of the population are prepared since 1992.

### *Methods*

We use methods applied in population epidemiology. The entire evaluated population is described by global health indicators as a whole, or in parts.

We follow no concrete illnesses or deaths.

Our analysis is based on modern multi-dimensional mathematical and statistical methods, such as fuzzy cluster analysis or spatial statistics. As a result we always get accurate mathematical specification of the level of the calculation's importance ( statistical level of significance).

Health risks are evaluated by several mathematical methods. Similarity of the indicator's value in connection to the point of the emission's source is evaluated with the assistance of

fuzzy cluster analysis. Similarity of the value and development of indicator in a village without respect to the source is evaluated by means of fuzzy C cluster analysis of the time periods. Randomness or determination of the indicator's value in a village is ascertained by methods of spatial autocorrelation. Individual year- indicators are added up to the short time periods to eliminate the age effect. Time periods also minimize the risks associated with working with small numbers that may affect the results when evaluations are made of conditions in individual small villages.

We therefore speak with mathematical accuracy whether the condition and development of a health indicator in a village are similar to those in the entire examined area, or whether they are different.

We also conclude with mathematical accuracy whether the value of indicator in a village is incidental, or whether there is some causal relationship either with events in the village, or with the wider situation that exists regardless of the boundaries of an individual village ( if similar phenomena are found to occur in clusters)

Only after we find out that a cluster of villages can be confirmed in which the indicator's value is worse for no incidental reason, but rather where there is an apparent connection with the wider surroundings, we start to investigate the possible cause, which, eventually, might turn out to be also the nuclear power plant.

## ***Results***

Our first conclusion is that both nuclear power plants are located in areas where most of the villages are small. The demographic structure of small villages is characteristic and it markedly influences the value of all health indicators. The population in small villages is usually older. It is therefore obvious that rural communities have higher morbidity and mortality than larger towns and cities. Higher long-term values of some indicators in comparison to those for Slovakia as a whole are caused by the age structure of the population and are comparable with the villages with a similar composition of the population, or even better.

## *Model Analysis of the Health Indicators*

### **The Nuclear Power Plant BOHUNICE**

The Bohunice power plant has been in operation for more than 20 years. We have no data that would give a clear picture of the initial state of health indicators. All the indicators are calculated from data recorded during the long, smooth operation of the nuclear power plant. Thus, all the values are "influenced", if such a condition exists.

#### *Selected Indicator of Reproductive Health :*

##### *Proportion of liveborn Children with low Birth Weight under 2500 Grams*

*( so called miscarried Children)*

It is assumed, that this indicator simply shows whether any particular cause exists, resulting in confirmable damage to children's development in its most sensitive stage. It partially compensates the information on the number of children with inborn defects. The value of such a statement would be higher, but it is unavailable for the whole Slovakia.

The period from 1993 to 2000 is investigated, divided into 6 short, partially overlapping time periods.

We evaluated the results by fuzzy c-cluster analysis where we look up villages with similar state and development.

We compared the state and development of indicator in individual villages by means of this analysis, regardless of the number of inhabitants. The result is not distorted by small numbers.

The result of the analysis is a table containing the average values of clusters, a graph of all clusters' trends and a map of villages coloured in accordance with the particular cluster in which they belong . By another method of space autocorrelation we continue investigating whether the state and trend in a village are accidental, or dependent on other circumstances in a village, or wider surroundings.

#### *Long- term Evaluation of the Percentage of Prematurely Born Children*

In the whole of Slovakia the share of prematurely born children varies from 6.6% - 6.8%

The trend shows a slight increase. Villages neighbouring the nuclear power plant Bohunice

are dividable into two limited clusters and trends. The values for the first cluster of villages (dark-blue line in the graph and colour on the map) are well below the national average and there is a trend towards their further decrease. These villages are located in a random pattern around the nuclear power plant Bohunice.

The dark green line in the graph and the same colour on the map indicate villages where the trend and state are similar to those in the whole of Slovakia. Villages not belonging exclusively to any particular cluster are depicted in light colours and they "rather belong to" one of the clusters according to the cluster's colour.

The coefficient of autocorrelation shows, that the situation in the entire area around the nuclear power plant Bohunice is of accidental nature. No clusters of unfavourable values of indicator have been found.

### Conclusion

A long-term favourable situation has been confirmed in the incidence of premature births in the investigated surroundings of the nuclear power plant Bohunice. The value of this indicator is accidental in all the villages investigated and the area as whole is below the average rate of premature births in the whole of Slovakia.

The operation of the nuclear power plant does not influence the reproductive health specified by this indicator.

Figure 2

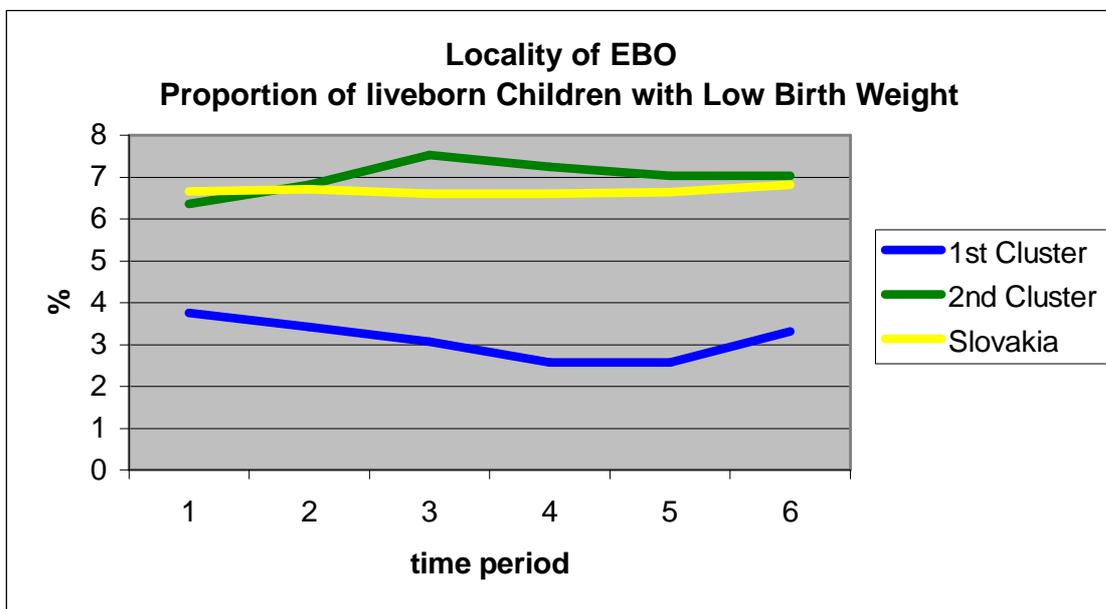
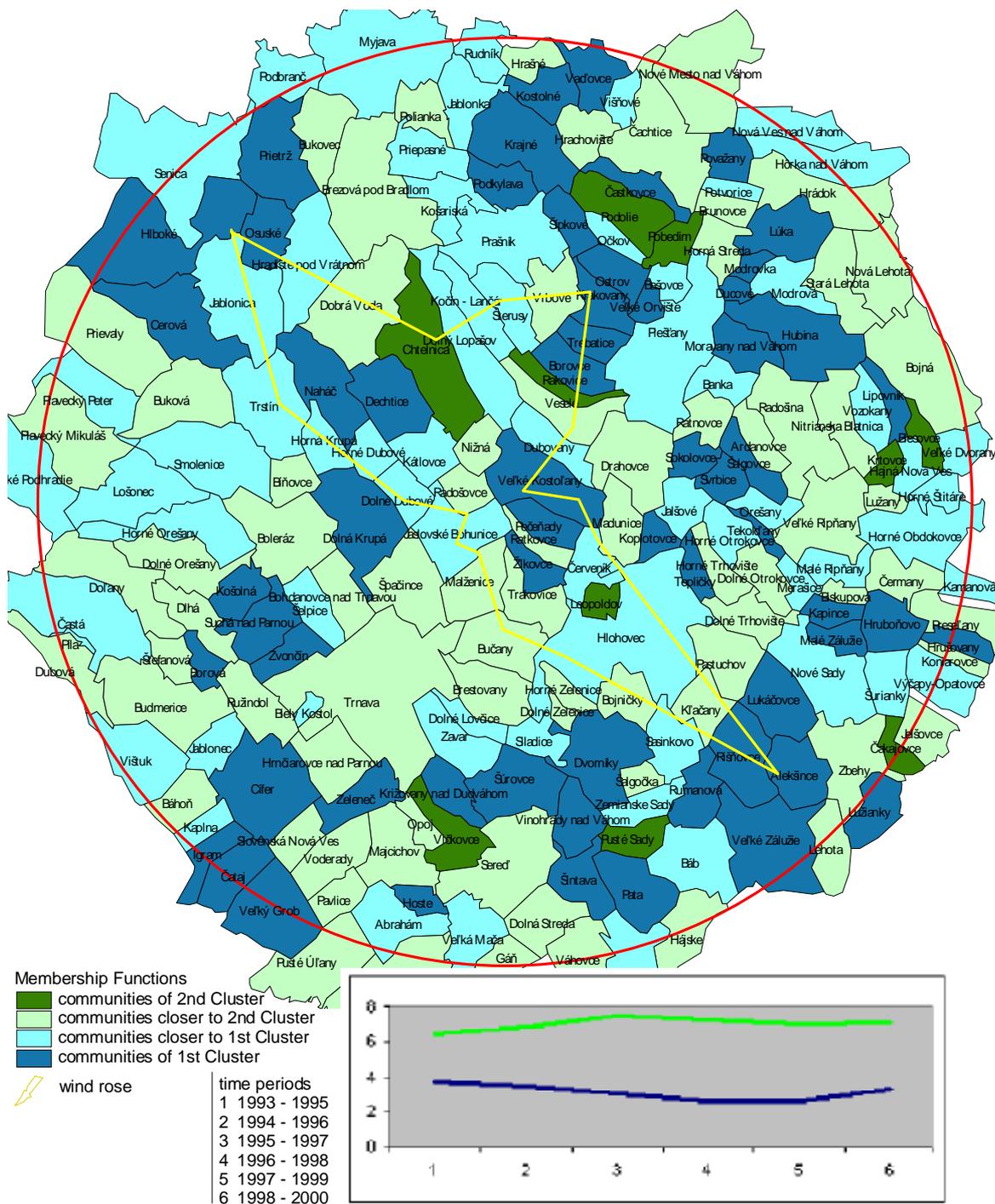


Figure 3

## Proportion of liveborn Children with low Birth Weight under 2500 Grams

Locality of NPP Bohunice + 30 km

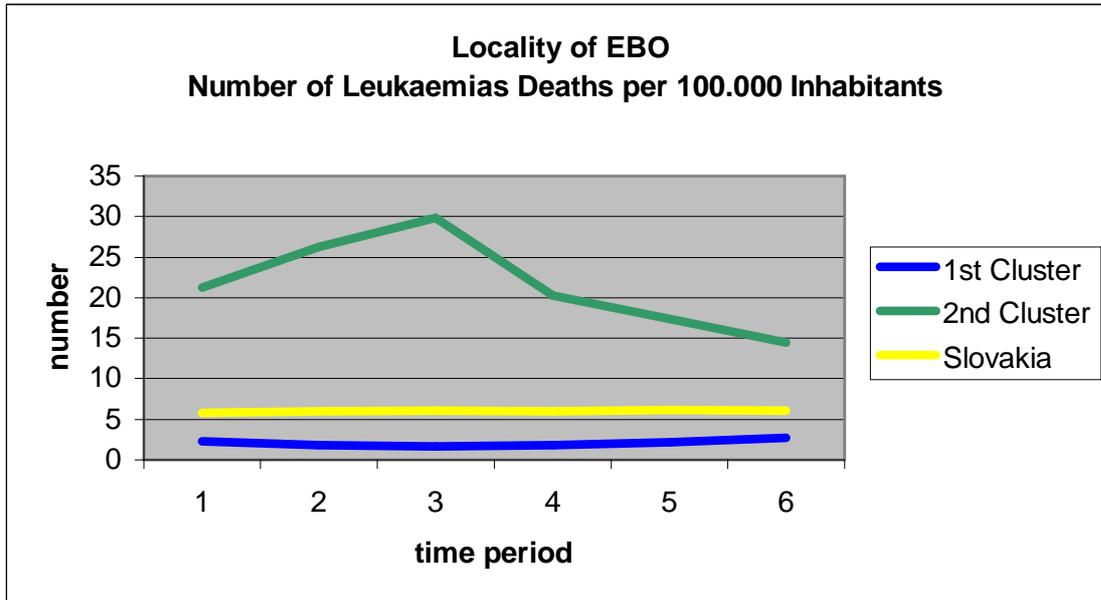
time periods of fuzzy c-cluster analysis



*Selected Indicator of Mortality: Proportion of Leukaemia's Deaths*

Incidence of Leukaemia Deaths is evaluated similarly.

Figure 4



*Conclusion from the evaluation of the proportion of leukaemia deaths in the surroundings of the nuclear power plant Bohunice*

The situation and development of the proportion of leukaemia deaths in the investigated surroundings of the nuclear power plant Bohunice has been found to be unaffected by the power plant's operation and the results of the investigation enable to conclude that the trends found are below those for the whole of Slovakia.

Two villages (Šúrovce and Bojná) appear to be an exception, but both of these rural communities are quite far from the nuclear power plant Bohunice and are located outside the area of potential risk determined by the prevailing winds, or water recipients of the Power Plant.

The value of this indicator is provably accidental in all of the investigated area and no clusters of villages with unfavourable situation were found.

Events in or outside the villages investigated have no provable influence on the indicator's value.

This finding is valid for all the villages within 30 km of the nuclear power plant Bohunice.

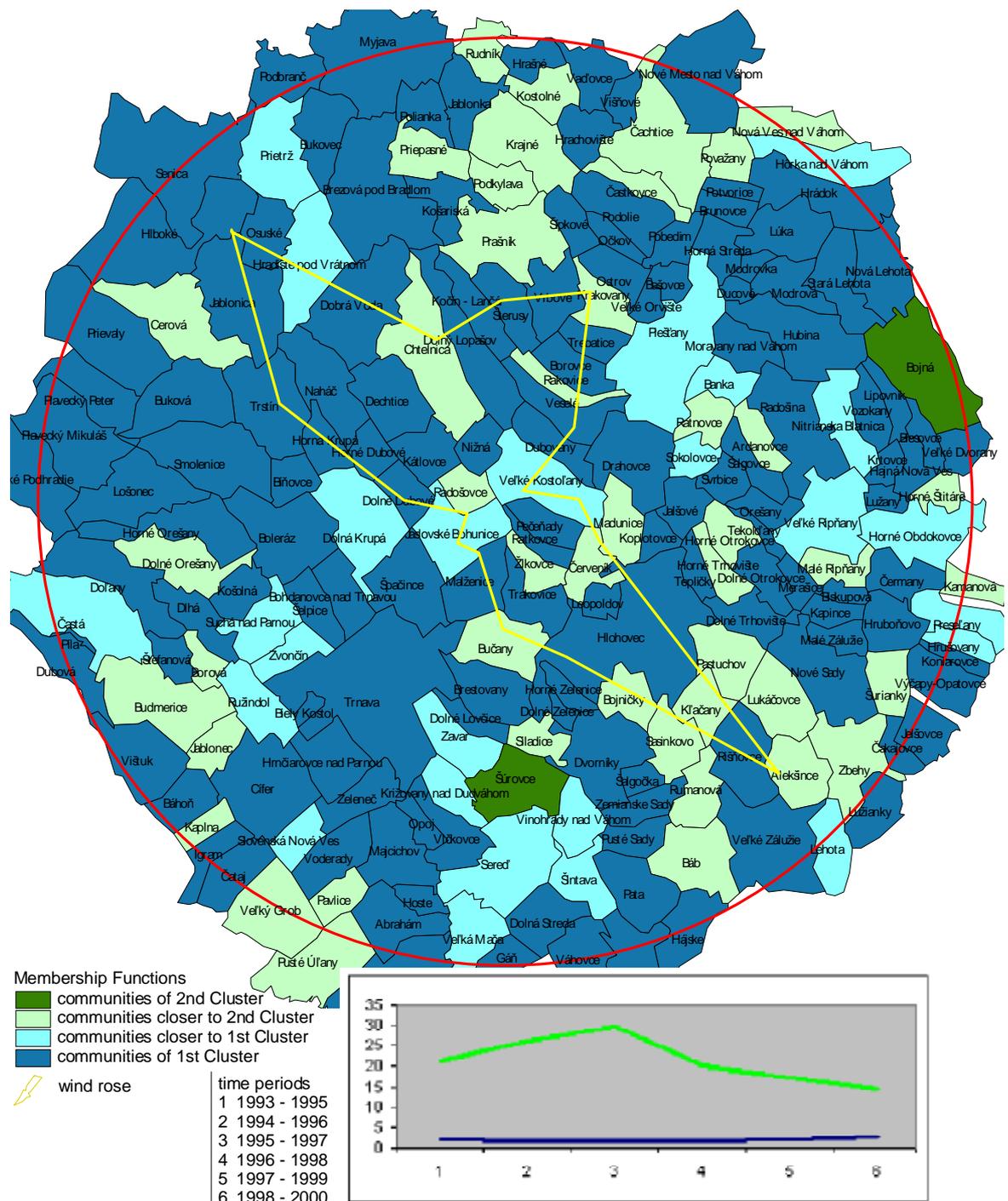
The operation of the nuclear power plant does not influence the rate of leukaemia deaths in the power plant's surroundings.

Figure 5

### Number of Leukaemias Deaths per 100.000 Inhabitants

Locality of NPP Bohunice + 30 km

time periods of fuzzy c-cluster analysis



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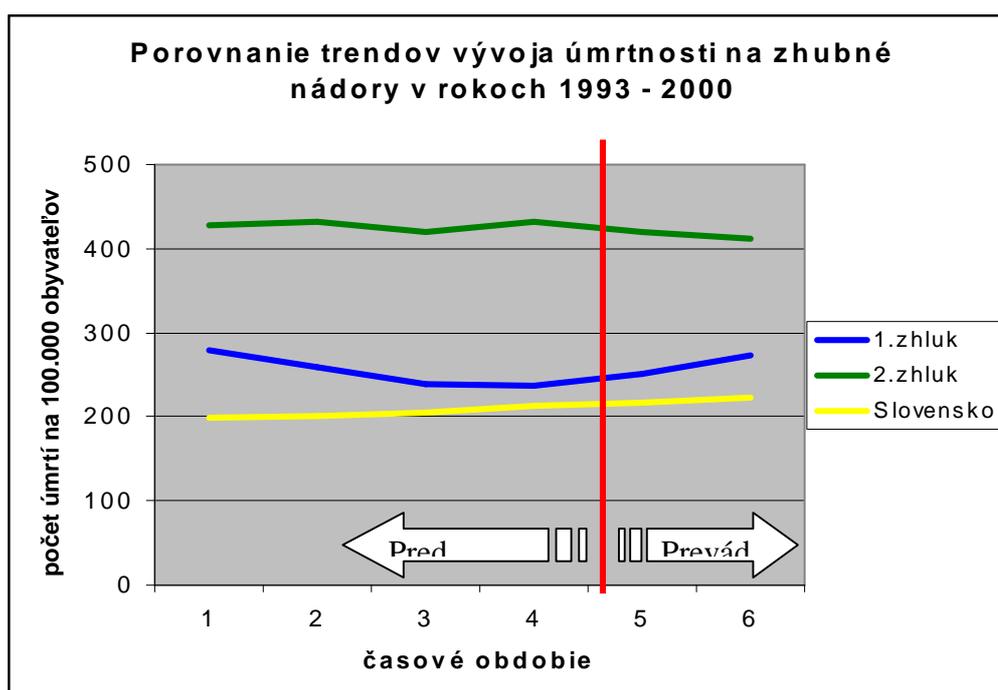
## The Nuclear Power Plant MOCHOVCE

The Mochovce nuclear power plant has been in operation for four years. We recorded the initial values of indicators and included them in the "Preoperation Safety Report". They serve as a comparative value in all the subsequent investigations of the influence of the Nuclear Power Plant's operation on the surrounding area. The values of indicators were calculated on the basis of data which had been recorded before the nuclear power plant was put in operation as well as during its operation (1998 - 2000). It is clear from the above stated, that the values of all indicators can be described as influenced but they should have become visibly "influenced" in the period investigated, if such a change really occurred.

*Selected Indicator of Mortality: Relative Number of total Cancer Deaths (per 100.000 Inhabitants)*

Evaluation of the situation and trends in villages by means of fuzzy cluster analysis and spatial autocorrelation

Figure 6



Cancer-caused mortality in the Mochovce region has been high during the entire investigation period regardless of the operation of the local nuclear power plant. Incidence of cancer in the region had been high long before the power plant was put into operation. Cancer cases increase in number also nationally. Our analysis has divided the villages in the Mochovce area into two distinct clusters, with high and very high cancer incidence - in both of the cases higher than the national average. Both the states are equally divided in all the surroundings of the Nuclear Power Plant Mochovce.

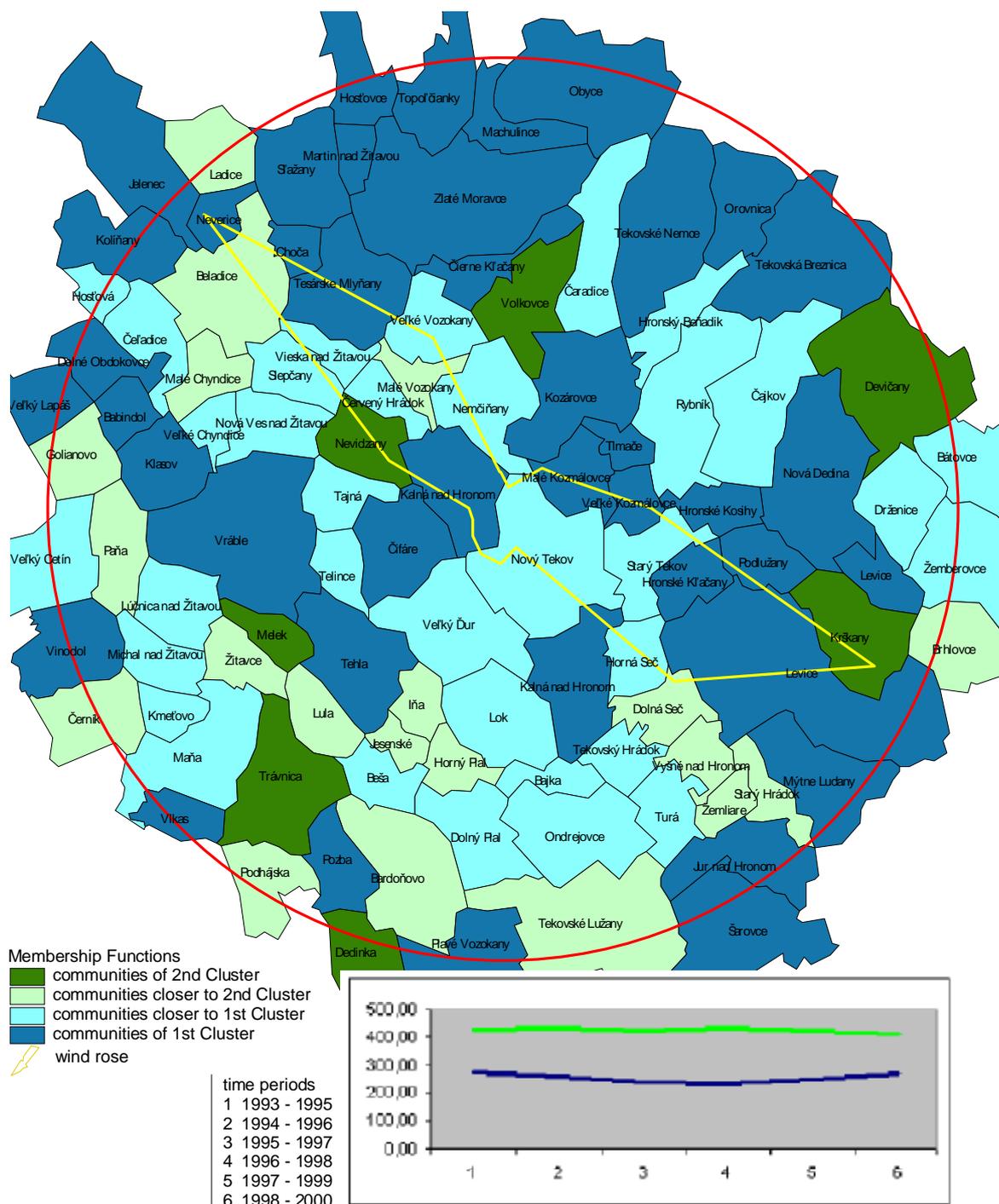
The value of this indicator is provably accidental in the entire investigated area and no clusters of villages with unfavourable situation were found. The trend was not influenced after the Nuclear Power Plant was put in operation.

Figure 7

### Number of total Cancer Deaths per 100.000 Inhabitants

Locality of NPP Mochovce + 20 km

time periods of fuzzy c-cluster analysis



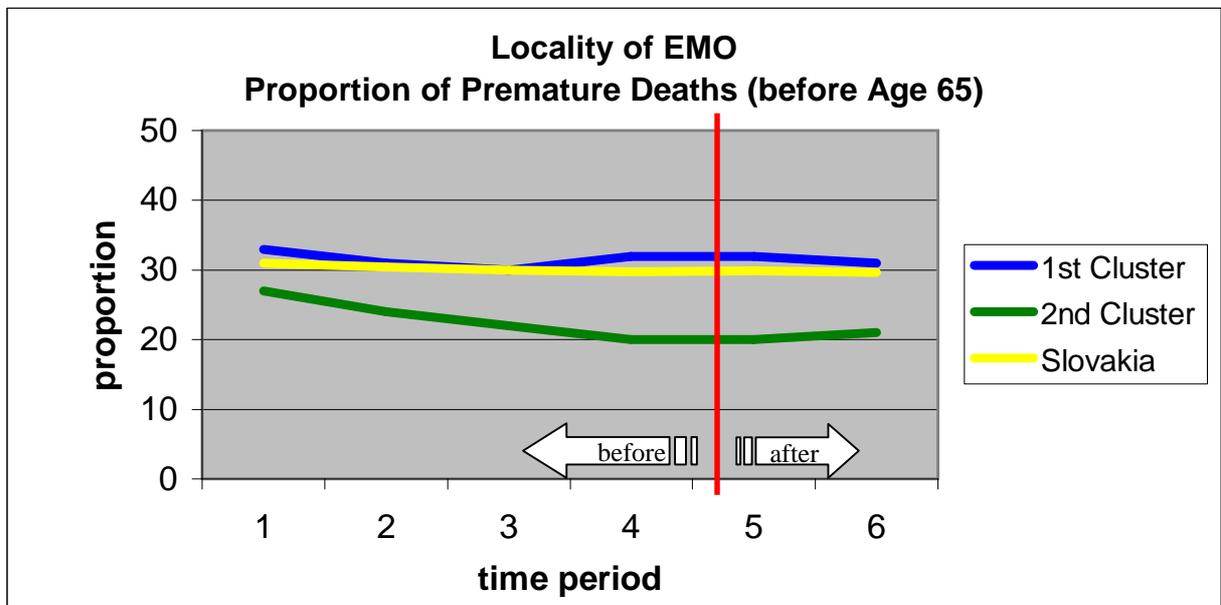
*Selected Indicator of Premature Mortality: Proportion of Premature Deaths*

Every death before the age of 65 is considered premature according to the World Health Organization (Geneva) instructions, regardless of sex.

Premature mortality in a region always signals a wider problem. Unfavourable economic situation is the most frequent factor involved. Another serious factor is environmental influence, as we can see, for example, in the vicinity of mines or huge industrial operations with high amount of exhalates.

Evaluation of the situation and tendency in the villages by means of fuzzy set of points and autocorrelation.

Figure 8



Premature deaths represent a stable proportion of all deaths in Slovakia.

It has long been observed that approximately 30 % of the nation's population die prematurely.

Our analyses suggest that there are two clusters of villages in the EMO region, both with a different situation and trend.

Both groups were close to each other around 1993 when our investigation was started. A majority of the population then began to move to the territory with the lower rate of premature deaths. We recorded a decrease by about one third in comparison with the initial situation. The second cluster of villages stagnates at the original value of 30 % with minimal decline.

Most of the villages are in the more favourable cluster with marked decrease of the number of premature deaths (dark- green) or are "rather with this condition and development" (light-green). There are larger towns mainly in the cluster with stagnation (Levice, Vráble, Zlaté Moravce).

All the values in all the villages are statistically provably accidental, which means that they are not influenced by environmental activity either in the village or in the wider area around it.

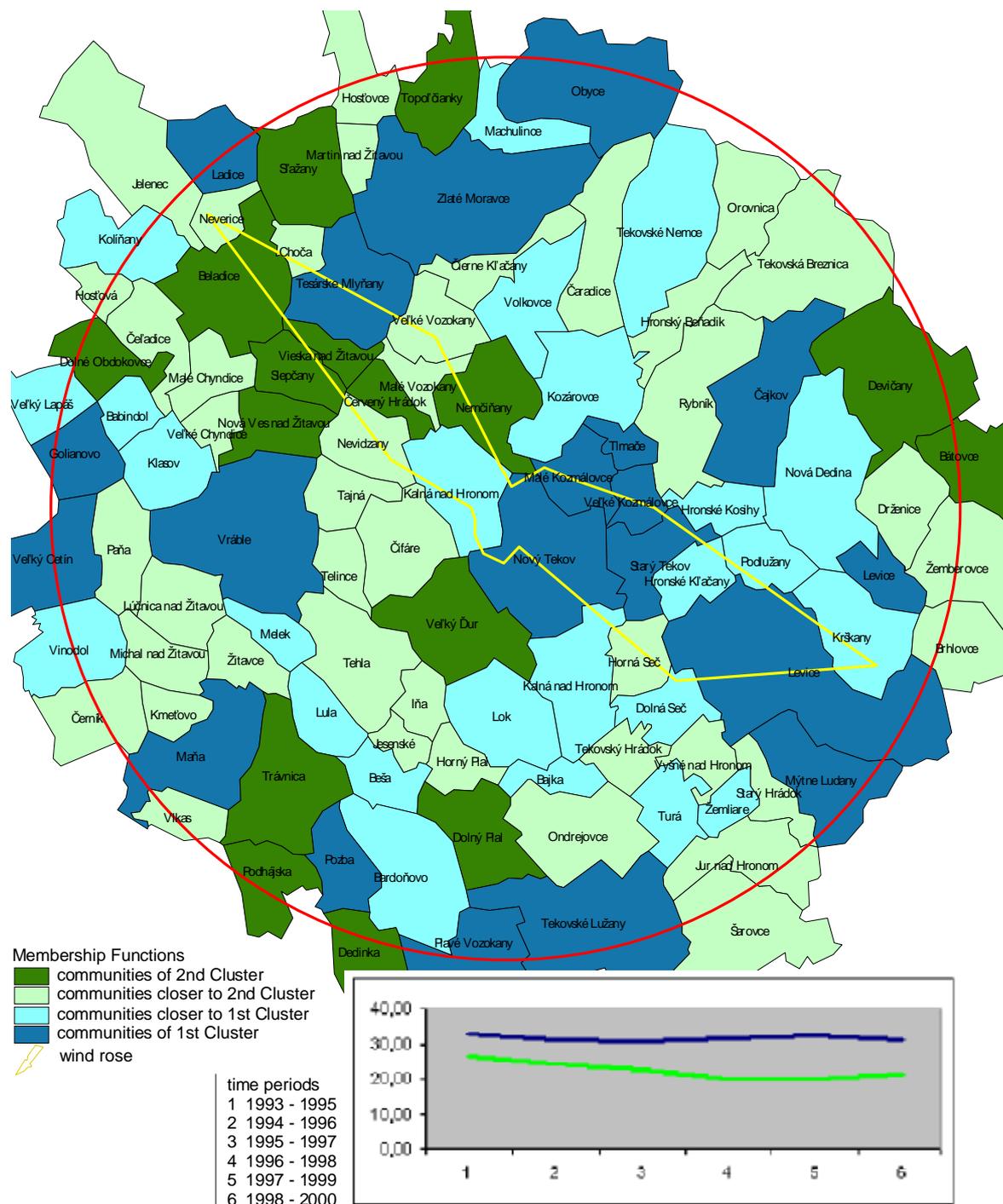
We assume, that the decline of the proportion of premature deaths is caused by markedly improved economic situation of the population thanks, in large measure, to the existence of the Mochovce nuclear power plant, which has provided many jobs and increased employment in the region.

Figure 9

### Proportion of Premature Deaths (before Age 65 Years)

Locality of NPP Mochovce + 20 km

time periods of fuzzy c-cluster analysis



## *Conclusions from the evaluation of the health condition of the populations in the territory of Nuclear Power Plants*

Conclusions drawn in keeping with the individual points of our objective are as follows:

- We considered the possibility of calculating all the health indicators recommended by the WHO in connection with environmental health, including detection of influence and human risks associated with industrial operation. We had chosen those indicators that are possible to calculate in Slovakia while observing the rules for determining such indicators (a total of 43 indicators).
- \* Chosen and analysed in detail were 15 indicators with at least partial relevance in all considerations of the influence of the operation of nuclear power plants
- Reviewed were all available epidemiological techniques and, after careful considerations and consultations with experts at a number of institutes specialised on mathematical and medical research, we included the most up-to-date methods of polydimensional supernumerary applying methods of fuzzy set of points and space supernumerary and neuron network after thorough consultation. Our aim was to determine dependences and causes with the highest possible level of accuracy.
- In the case of 15 health indicators in the territory of the "old" nuclear power plant Bohunice we concluded, that after 20 years of operation no places or localities can be found that would be at risk or where adverse impact or damage has been observed or confirmed, nor are there any territories that could be described as being at risk, either in the direction of prevailing winds or along the rivers carrying away waste water from the power plant. All the parameters are at the level found in the wider area, or even better. The entire area around the nuclear power plant seems, from the demographic point of view, to be "a town", even though it is composed of a large number of small villages. We assume, that the Nuclear Power Plant has a significant influence on the health condition of the local population, but in a positive sense. A large number of people from many local villages are employed there. These people have to lead a healthy life precisely because they work in units that have strict rules and operational discipline. Their lifestyle is similar to that of the people living in towns. They have a high income, combined with the

advantage of living in rural areas with cleaner air, lower air pollution and lower levels of exhaust fumes from motor vehicles .

- In the case of the 15 health indicators in the territory of the "new" nuclear power plant Mohave we confirmed a mathematically significant influence on the whole area as well. Again in a positive sense only. There are apparent clusters of villages with low average and premature female death rates. This locality was always further away from industrial and cultural centres than the nuclear power plant Bohunice. In the past there was always scarcity of job opportunities in this region and, consequently, also greater poverty and greater morbidity. Already the construction of the power plant created now job opportunities. Even more jobs have become available with the putting of the power plant into operation and the situation keeps improving. We find this effect to be very similar to that at Bohunice: indirectly positive even if a little bit unexpected.

We can safely conclude, that objective and comprehensive evaluation of the health of the population of Slovakia is possible. Enough solid and reliable proofs are available to justify the conclusion that, regardless of the length of the power plants' operation, no unfavourable impacts on human health on their territory have been detected even by the most sophisticated research carried out by a large, multidisciplinary team of researchers from various fields of science.